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(54) **CABLE BEND RELIEF FOR FIBER OPTIC SUB-ASSEMBLIES AND METHODS OF ASSEMBLING**

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(51) **Int. Cl.**

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G02B 6/42 (2006.01)
G02B 6/44 (2006.01)

(52) **U.S. Cl.**

CPC ***G02B 6/428*** (2013.01); ***G02B 6/4478*** (2013.01); *Y10T 29/49826* (2015.01)

(58) **Field of Classification Search**

CPC G02B 6/428; G02B 6/3887; G02B 6/4478; G02B 6/3807

See application file for complete search history.

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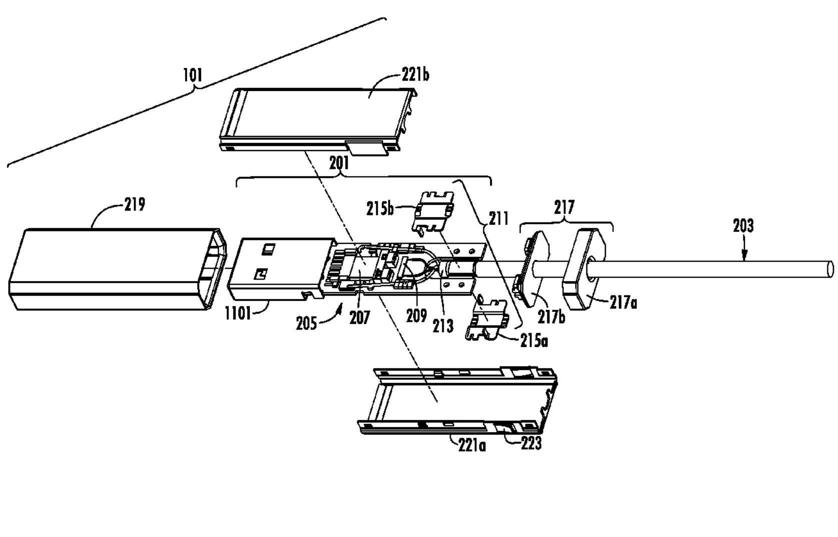
Primary Examiner — Rhonda Peace

(57) **ABSTRACT**

Fiber optic cable sub-assemblies having an end cap device with an internal bend relief are disclosed. In one embodiment, the fiber optic cable sub-assembly has at least one optical fiber of a fiber optic cable attached to a circuit board with the end cap device providing strain relief to the fiber optic cable. The circuit board includes an active optical component in operable communication with the optical fiber for forming an active optical cable (AOC) assembly. Additionally, a strain relief device may be used for attaching an end portion of the fiber optic cable to the circuit board, thereby forming the cable sub-assembly. Methods of assembling the fiber optic cable sub-assembly are also.

41 Claims, 11 Drawing Sheets



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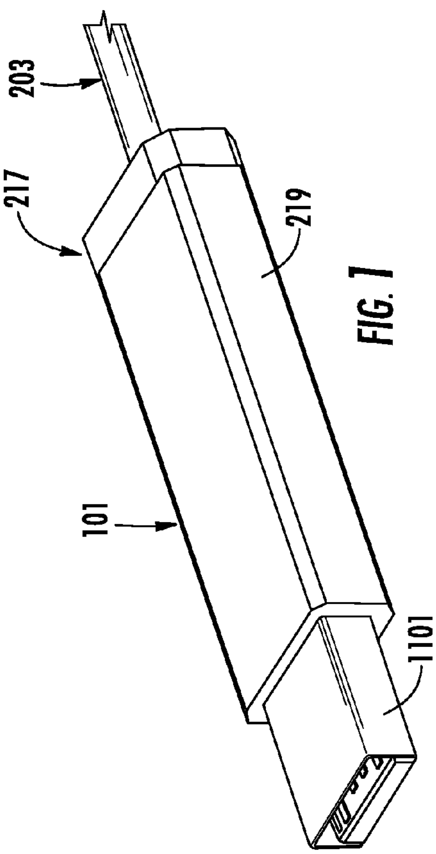
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FIG. 1

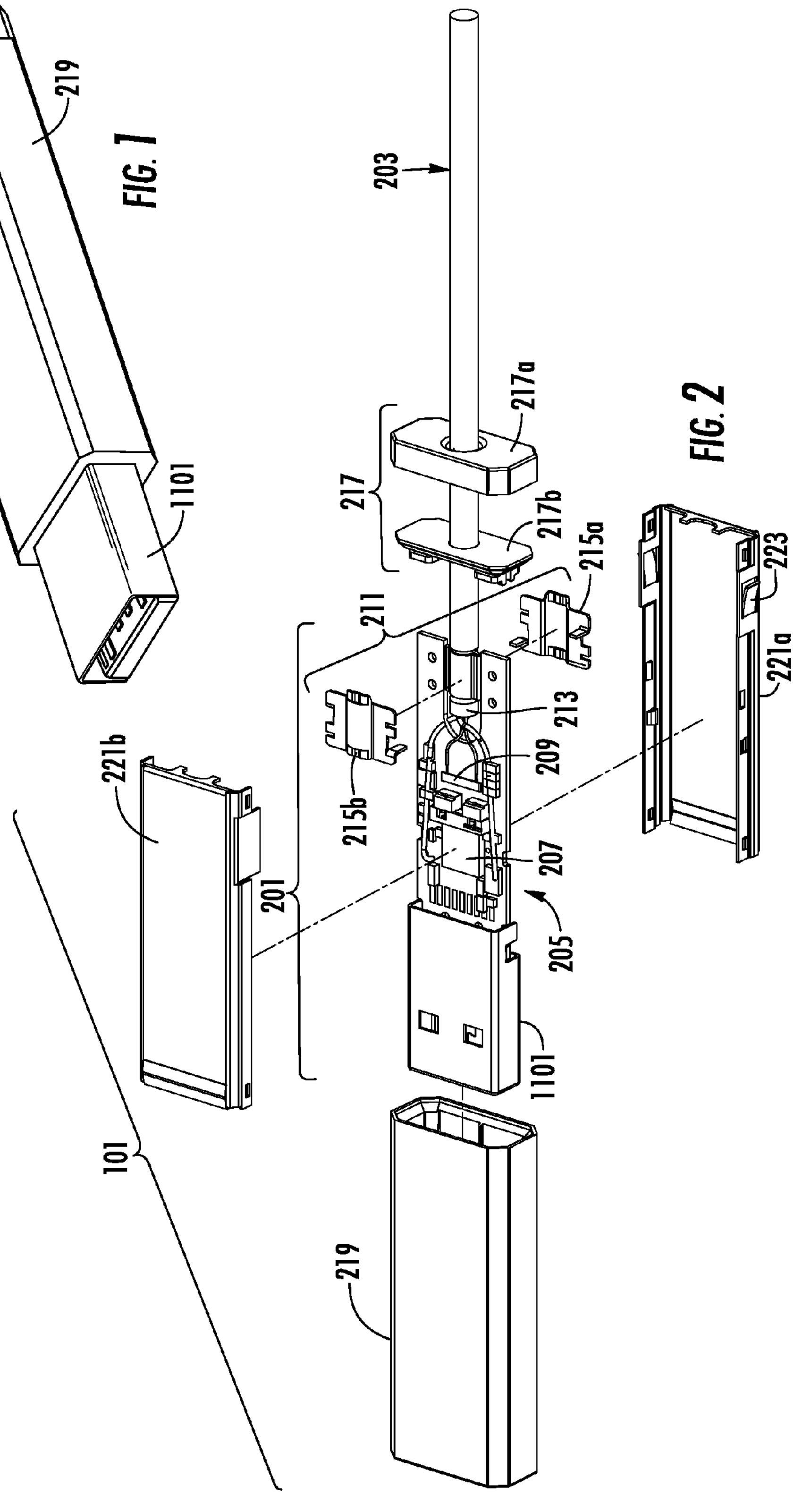
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FIG. 2

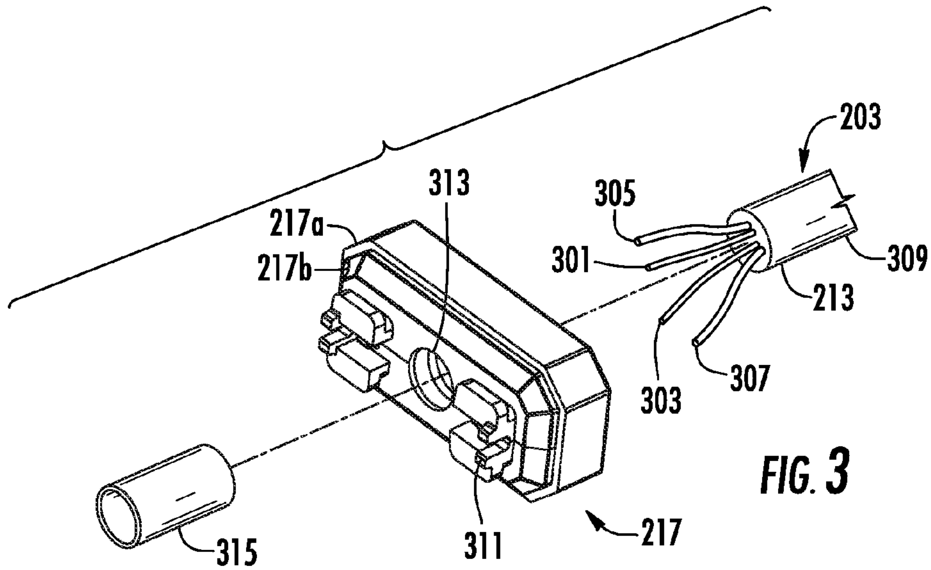
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FIG. 3

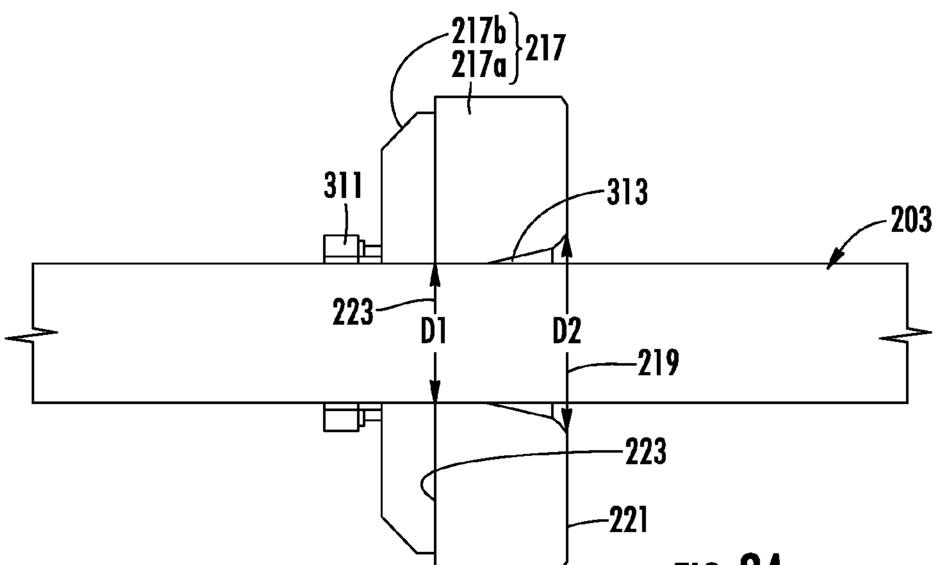
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FIG. 3A

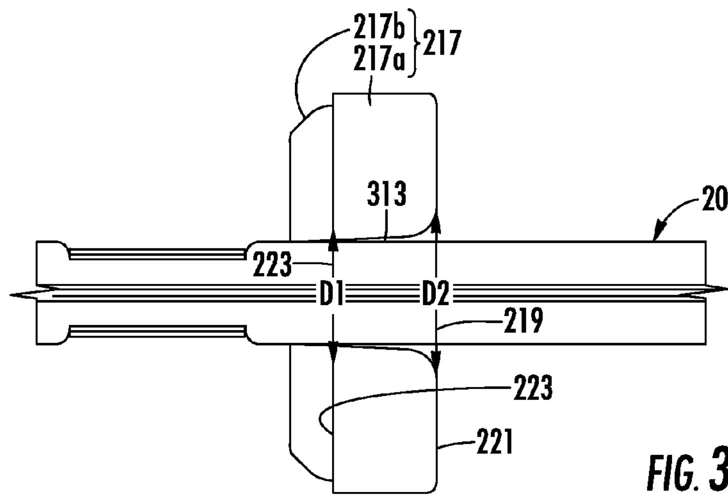

FIG. 3B

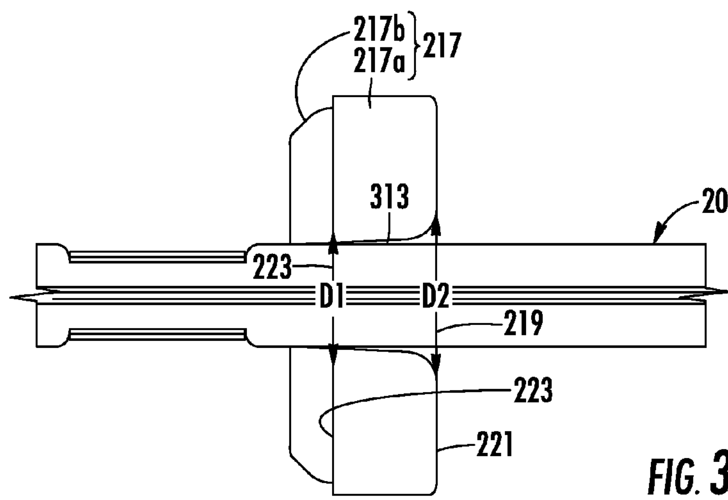

FIG. 3C

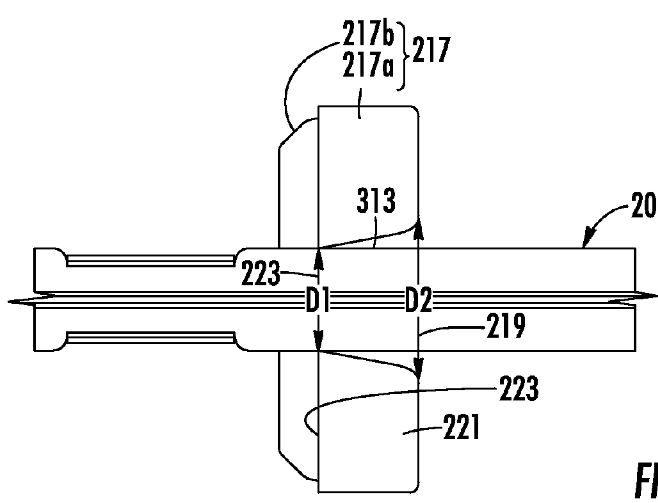

FIG. 3D

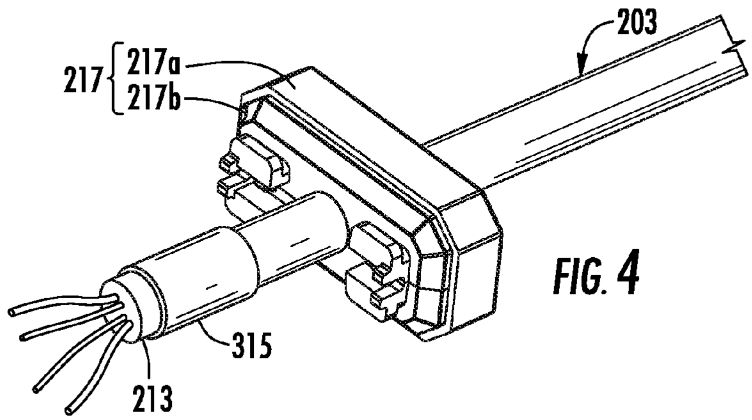
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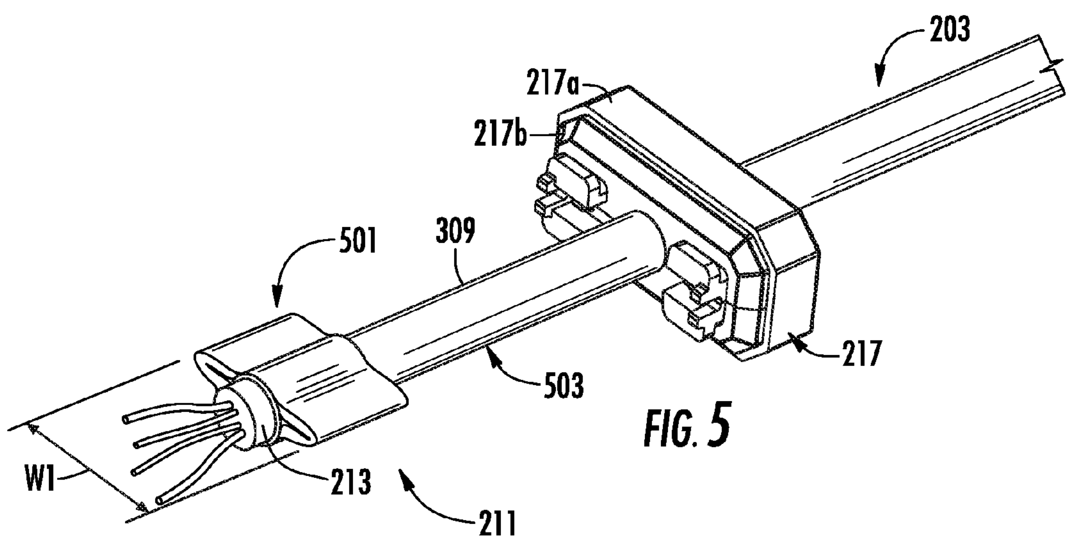
FIG. 4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503
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W1
213
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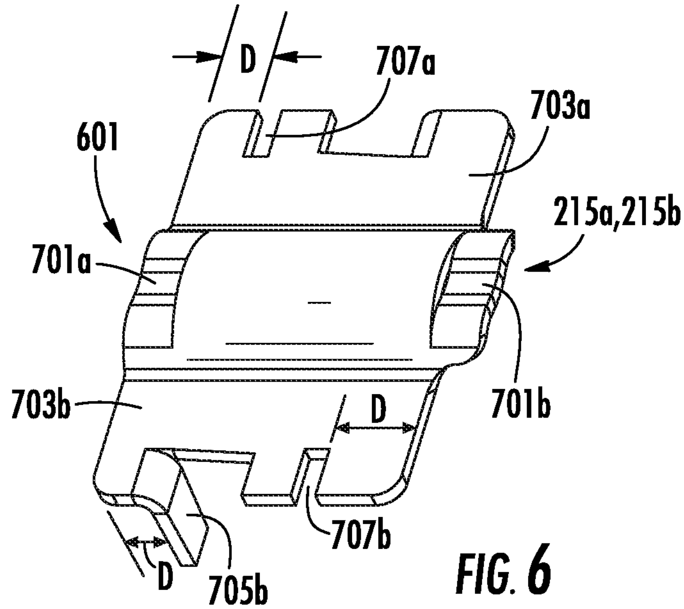
FIG. 5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707b
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705b

FIG. 6

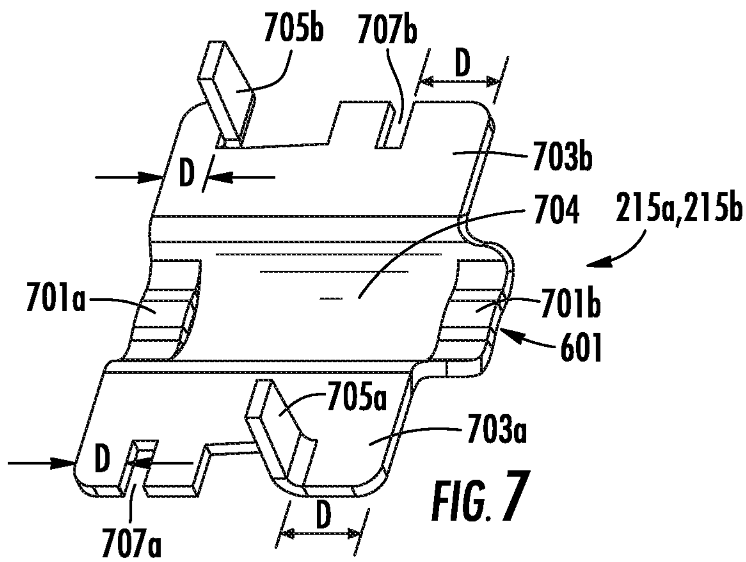
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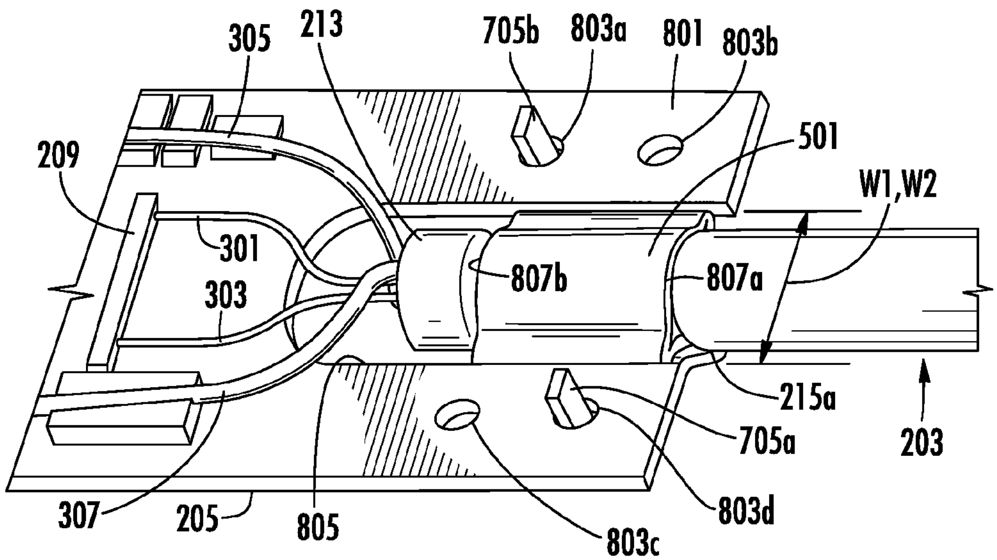
FIG. 7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803b
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805
803d
803c

FIG. 8

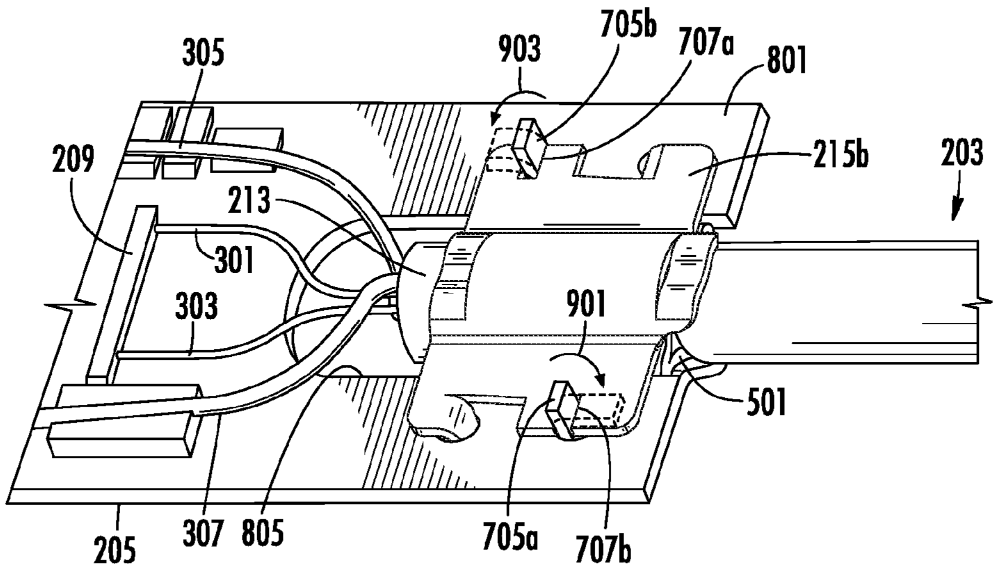
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FIG. 9

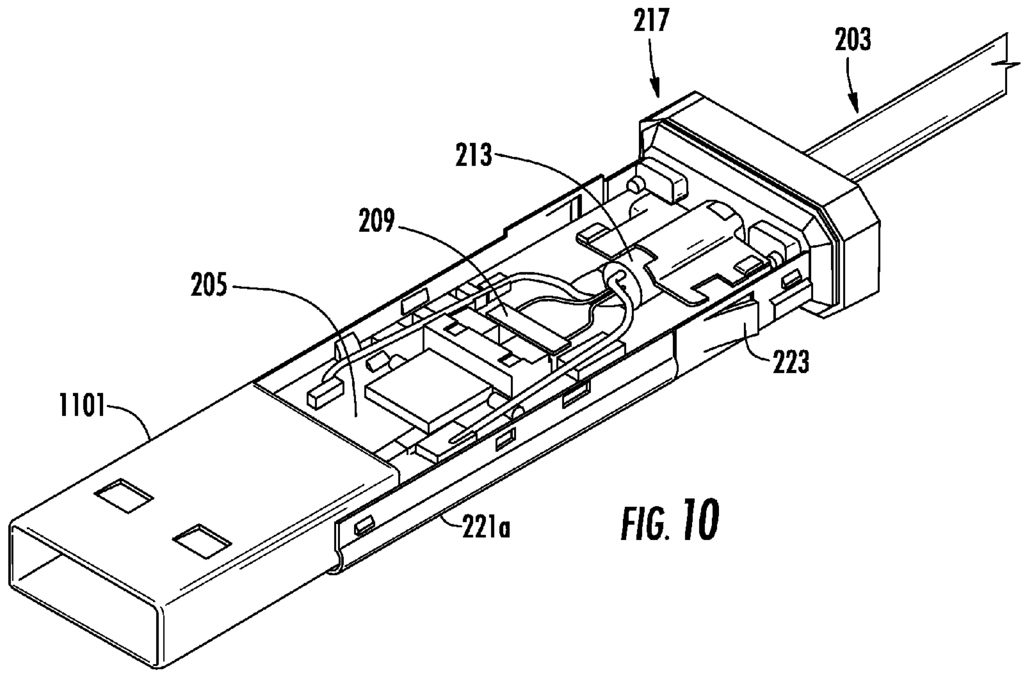


FIG. 10

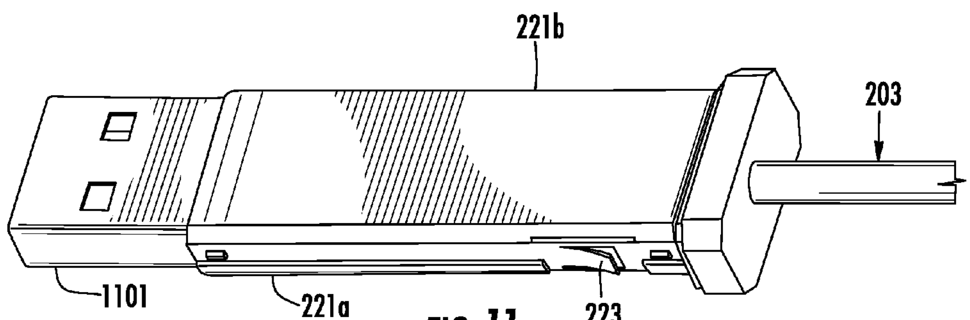


FIG. 11

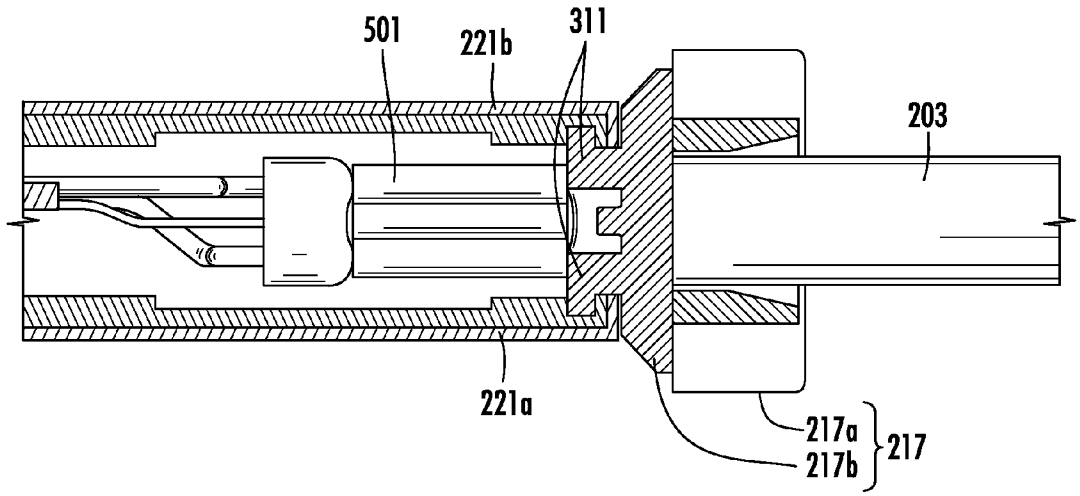
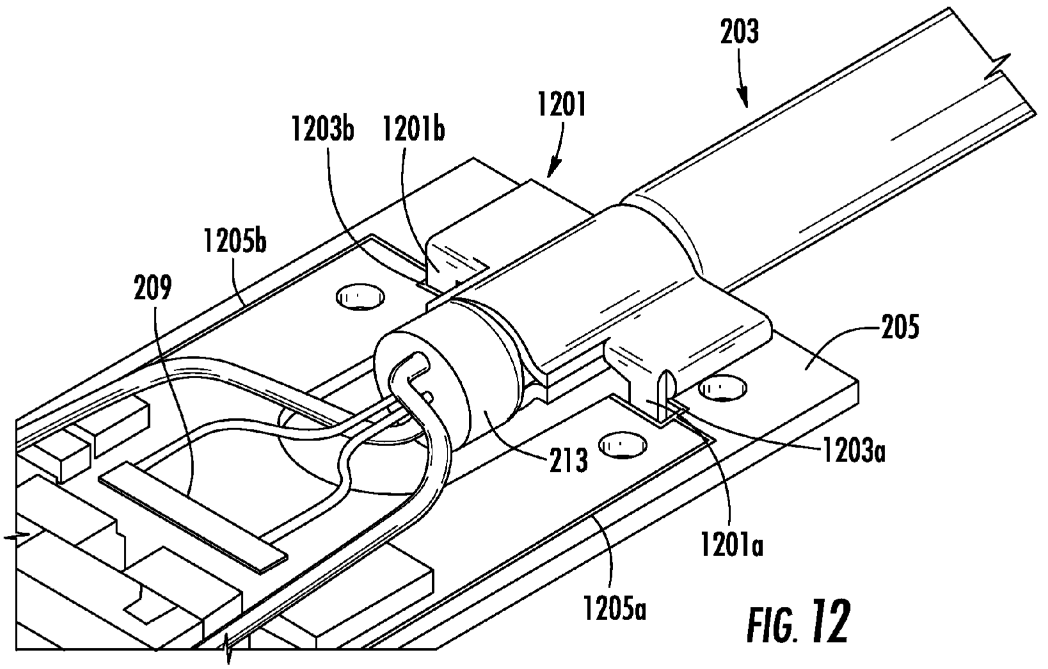


FIG. 11a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1205a

FIG. 12

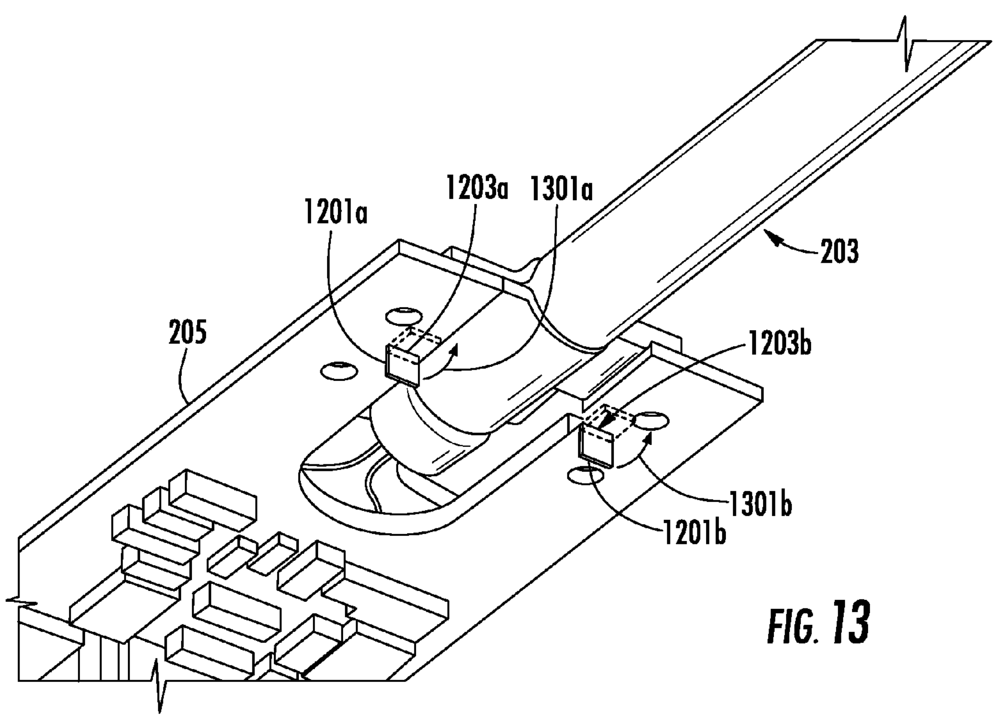
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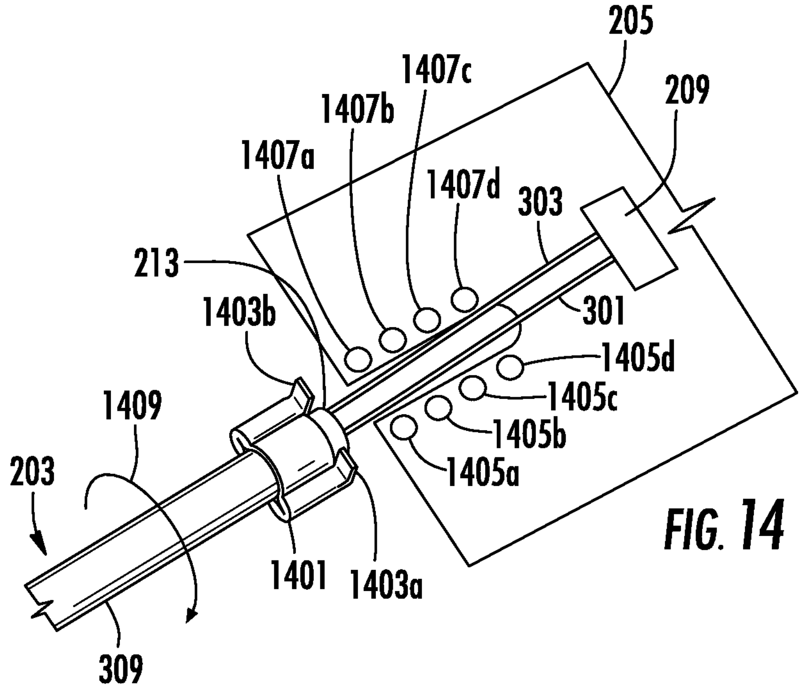
FIG. 13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1401
1403a
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FIG. 14

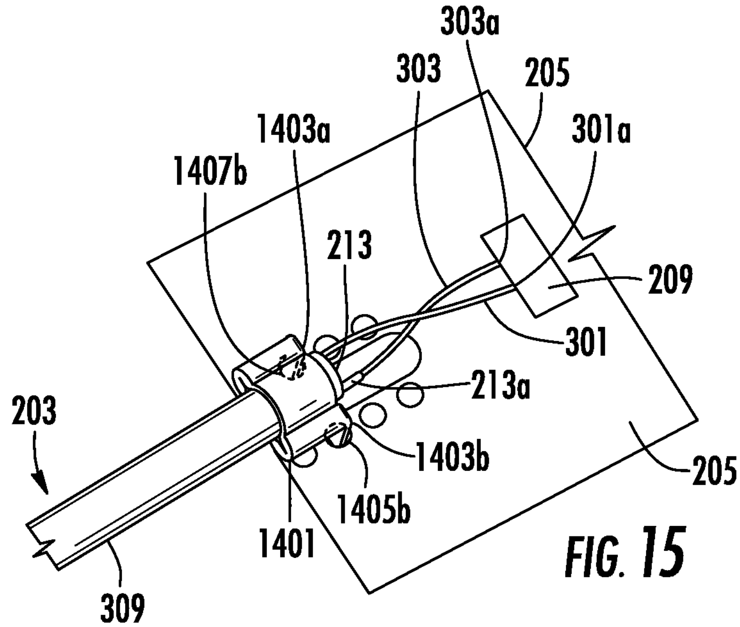
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FIG. 15

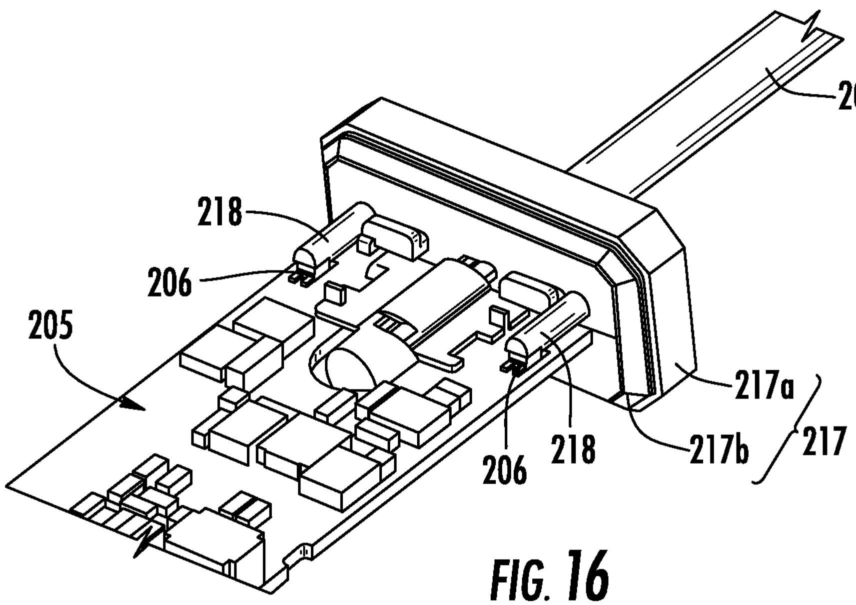
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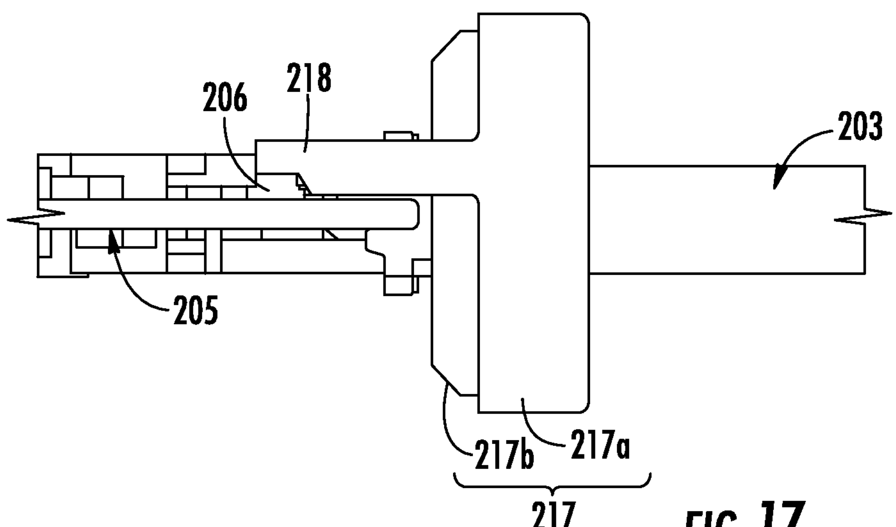
FIG. 16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217

FIG. 17

CABLE BEND RELIEF FOR FIBER OPTIC SUB-ASSEMBLIES AND METHODS OF ASSEMBLING

BACKGROUND

1. Field of the Invention

The present invention relates generally to fiber optic cable sub-assemblies and methods of assembling and, more particularly, to fiber optic cable sub-assemblies including cable bend relief provided by an end cap device.

2. Technical Background

Fiber optic cables are known for their ability to transmit data at faster rates than cables having electrical conductors. Typically, fiber optic cables have been used in telecommunication networks, data centers, private network and the like. However, with the increasing demand for high-speed data transmission for consumer electronic devices such as smart phones, tablets, laptop computers, digital cameras, video displays such as televisions and the like fiber optic cables are being considered for replacing conventional electrical cables for high-speed data transmission applications.

Consequently, new fiber optic cables are being developed for attaching and making optical connections with electronic devices such as host and client devices. For example, many consumer electronic devices have one or more Universal Serial Bus (USB) electrical ports for establishing an electrical connection with an external device. The latest USB specification (USB 3.0) supports a data rate of 5 Gb/s, which is ten times faster than the previous USB specification (USB 2.0), and this latest version is still backwards compatible with the USB 2.0. As fiber optic cable designs begin to migrate into this space to support faster data rates, they still must be backwards compatible with the installed base of USB ports. Active optic cable (AOC) assemblies allow the use of the optical fibers as the transmission medium between the connectors on the ends of the cable instead of the conventional copper wires; however, the optical signals conveyed by the optical fibers are converted into electrical signals (i.e., optical-to-electrical (O-E) conversion) and vice versa (i.e., electrical-to-optical (E-O) conversion) so that the connector has an electrical interface to be compatible with the installed base of consumer devices.

In other words, for an AOC fiber-optic cable to be connected to a USB port, it must be terminated with a USB electrical interface configured for transmitting electrical signals at the port connection. Unlike a fiber optic cable used for telecommunications that experiences relatively few connections and disconnections in a controlled environment, a fiber optic cable use for consumer applications will experience frequent connections and disconnections in a variety of environments. Consequently, the mechanical connection between the fiber optic cable and the connector that terminates the cable must be robust for the large number of mating/unmating cycles expected over its lifetime.

Conventional fiber optic cable assemblies typically employ a crimp band that is secured (i.e., crimped) to a crimp body disposed on the end portion of the fiber optic cable. Typically, the strength members of the fiber optic cable are exposed and disposed between a barrel of the crimp body and secured to the same using the crimp band for strain relieving the cable to the connector such that pulling forces on the cable are transferred to the connector housing so stress and/or strain is not transmitted to the optical fiber. Such conventional strain relief configurations can add considerably to the overall length of the connector housing and are not suitable for active optic cable (AOC) assemblies since the connector footprint is different. Moreover, the size and appearance of the connector may larger due to a boot or overmolded housing portion for providing cable bend relief to the assembly. Consequently, there is an unresolved need for a compact and easy to manufacture cable bend relief and/or a strain-relief assembly for securing a fiber optic cable to a sub-assembly of an active optic cable assembly or the like in a quick, reliable and cost-effective manner.

SUMMARY

The present disclosure is directed to fiber optic cable sub-assemblies that provide cable bend relief using an end cap of the connector. One embodiment is directed to a fiber optic cable sub-assembly having a fiber optic cable including at least one optical fiber and an end cap. The end cap has a passageway extending from a rear opening at a rear end of the end cap to a front opening at a front end of the end cap that receives a portion of the fiber optic cable, wherein the rear opening is larger than the front opening for providing cable bend relief. In other words, no discrete components are required for cable bend relief since the passageway of the end cap provides a bend surface for protecting the cable during side-bending. The sub-assembly may also include a circuit board having an active optical component in operable communication with the optical fiber of the cable. This embodiments may also include a strain relief device for attaching the cable to the circuit board as desired.

In other embodiments, the disclosure is directed to a fiber optic cable assembly having a fiber optic cable including at least one optical fiber and an end cap. The end cap has a passageway extending from a rear opening at a rear end of the end cap to a front opening at a front end of the end cap that receives a portion of the fiber optic cable, wherein the rear opening is larger than the front opening for providing cable bend relief. The assembly also includes a circuit board including an active optical component in operable communication with a first end of the optical fiber, along with a strain relief device attaching an end portion of the fiber optic cable to the circuit board. The assembly may also include a shield for housing a portion of the circuit board and the active optical component.

Other aspects of the disclosure are directed to methods of assembling a fiber optic cable sub-assembly. One explanatory method includes the steps of providing a fiber optic cable including at least one optical fiber, providing an end cap having a passageway extending from a rear opening to a front opening where the rear opening is larger than the front opening for providing cable bend relief, threading an end of the fiber optic cable into the rear opening of the passageway; and operably attaching the at least one optical fiber of a fiber optic cable to an active optical component of a circuit board. Of course, other methods and steps are possible such as described in the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects and advantages of the present invention are better understood when the following detailed description of the invention is read with reference to the accompanying drawings, in which:

FIG. **1** is a perspective view of an assembled end of an explanatory fiber optic cable assembly;

FIG. **2** is a partially exploded view of the fiber optic cable assembly of FIG. **1**;

FIG. **3** is a partially exploded view of portions of the fiber optic cable assembly of FIG. **1** including an end portion of a fiber optic cable, an end cap device, and a sleeve of an example strain relieve device;

FIGS. **3**A-**3**D are partial cross-sectional views showing a passageway of the end cap having a cable bend relief feature integrated into the passageway;

FIG. **4** illustrates a step of inserting the end portion of the fiber optic cable through the end cap device and through the sleeve of FIG. **3**;

FIG. **5** illustrates the sleeve of FIG. **4** being clamped to the end portion of the fiber optic cable;

FIG. **6** illustrates a top perspective view of an example mounting bracket of the example strain relieve device;

FIG. **7** illustrates a bottom perspective view of the mounting bracket of FIG. **6**;

FIG. **8** illustrates a first mounting bracket being positioned with respect to a circuit board for attaching the end portion of the fiber optic cable to the circuit board;

FIG. **9** illustrates a further embodiment using first and second mounting brackets positioned with respect to the circuit board and the step of crimping the mounting brackets to the circuit board to capture the clamped sleeve within an opening in the circuit board;

FIG. **10** illustrates the step of engaging the end cap device such that a carrier structure supports an end of the circuit board and the step of attaching a first shielding member about the circuit board;

FIG. **11** illustrates the step of attaching a second shielding member with respect to the first shielding member;

FIG. **11**A is a schematic cross-sectional view showing how the carrier structure is secured to the shield;

FIG. **12** illustrates a top perspective view of another example clamped sleeve for attaching the end portion of the fiber optic cable to the circuit board;

FIG. **13** is illustrates a bottom view of the example clamped sleeve of FIG. **12**;

FIG. **14** illustrates yet another example clamped sleeve for attaching the end portion of the fiber optic cable to the circuit board;

FIG. **15** illustrates a step of attaching the clamped sleeve of FIG. **14** to a circuit board;

FIG. **16** depicts a perspective view of another sub-assembly end cap having light pipes in optical communication with light emitted devices on a circuit board; and

FIG. **17** a partial cross-sectional view of the sub-assembly of FIG. **16**.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which example embodiments of the invention are shown. Whenever possible, the same reference numerals are used throughout the drawings to refer to the same or like parts. However, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. These example embodiments are provided so that this disclosure will be both thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

Although described with respect to an active optical cable (AOC) sub-assemblies and cables, the concepts of the disclosure may be used with any suitable cable having a communication element such as an electrical conductor or optical fiber. For instance, the sub-assembly may be a passive optical cable assembly or an active electrical cable assembly having a circuit board secured to a cable and/or be in communication with the communication element. A passive optical cable assembly has connectors with an optical interface and may include electrical connections as desired. On the other hand, the AOC converts an inputted electrical signal at the connector interface to an optical signal (i.e., an electromagnetic signal) appropriate for transmission along the optical fibers and then converts the transmitted optical signal to an electrical signal at the output side at the other connector interface. In other examples, the electromagnetic signal can comprise RF signals (e.g., at 160 GHz) or other suitable signals. AOC assemblies may include an active optical component such as integrated chips, photodiodes, VCSEL and/or other electro-optic active components at or near the connector for converting optical signals to electrical signals and vice-versa. The active components may be aligned with a total internal reflection (TIR) block, a lead frame, ferrule or other structure for aligning and transmitting/receiving the optical signals to the active components without undue signal loss. The TIR block, lead frame, ferrule or the like receive and are attached to one or more optical fibers for providing optical communication to active components.

By way of illustration purposes, FIG. **1** shows an assembled end of an explanatory fiber optic cable assembly **101** having an AOC connector attached to a fiber optic cable. Specifically, FIG. **1** shows fiber optic cable assembly **101** having a standard A USB configuration, but other configurations are possible such as Micro-B, receptacle A or even other non-USB protocols according to the concepts of the application. Example features of the fiber optic cable assembly **101** are illustrated with initial reference to the exploded view shown in FIG. **2**. Specifically, the fiber optic cable assembly **101** includes a fiber optic cable sub-assembly **201** comprising a fiber optic cable **203**. Although the concepts are described in detail for attaching fiber optic cables to circuit boards the concepts may be used for attaching electrical cables as well.

As shown in FIG. **3**, the fiber optic cable **203** can include at least one optical fiber such as the first optical fiber **301** and the second optical fiber **303** illustrated in FIG. **3**. While two optical fibers are illustrated, further examples of fiber optic cables can include a single optical fiber or more than two optical fibers such as four optical fibers as desired. The at least one optical fiber **301**, **303** is configured to transmit light across a fiber length between opposed ends of the fiber optic cable assembly **101**. As further illustrated in FIG. **3**, the fiber optic cable **203** can also include optional electrical wires **305**, **307** that may be configured to provide electrical power to components of a circuit board **205** or allow power or data signals to be passed through the fiber optic cable **203**. While electrical wires **305**, **307** may comprise two wires as shown, and in further examples a single conducting cable may be provided or more than two wires may be provided as desired.

Still referring to FIG. **3**, the fiber optic cable **203** may further include a cable jacket **309** housing the at least one optical fiber **301**, **303**. As further shown, the cable jacket **309** may also house electrical wires **305**, **307** if provided. The cable jacket **309** can at least partially encapsulate one or more of the optical fibers **301**, **303** and/or the electrical wires **305**, **307**. Alternatively, or in addition, the cable jacket **309** may optionally define an internal through passage (i.e., a cavity) configured to receive one or more of the optical fibers **301**, **303** and/or the electrical wires **305**, **307**. The cable jacket **309** can comprise rubber, plastic, resin or other suitable material configured to insulate and/or protect optical fibers **301**, **303** and/or the electrical wires **305**, **307** from damage. Although not shown, the cable jacket **309** may also be provided with one or more optional strength members, such as Kevlar®

material or metal wires to further strengthen the cable jacket **309** by increasing the strength and/or help maintain a minimum bend radius for the fiber optic cable. Simply stated, the concepts disclosed herein may be used with any suitable cable type or construction, or decorative features as desired. As an example of a decorative feature, the cable jacket may have any suitable color such as black, white or transparent as desired.

FIGS. **3A-3D** show partial cross-sectional views of the end cap device **217** having an end cap **217***a* and a carrier **217***b* as shown. End cap **217***a* has a passageway **313** extending from a rear opening **219** at a rear end **221** of the end cap **217***a* to a front opening **223** at a front end **225** of the end cap **217***a* that receives a portion of the fiber optic cable **203**. Carrier **217***b* also has a passageway for the cable as shown and may have a carrier structure **311** for supporting an end of the circuit board. Carrier structure **311** may be integrally formed with the end cap **217***a* or not depending on the desired construction. As shown by FIGS. **3A-3D**, the rear opening **219** has a dimension D2 that is larger than a dimension D1 of the front opening **223** for providing cable bend relief. In other words, the cable bend relief structure is integrally formed within the passageway **313** of end cap device **217***a* to allow a gentle bend radius for the cable near the end cap device. In other words, the fiber optic cable **203** may be bent sideways relative to the longitudinal axis of the connector at up to 90 degrees or more while allowing the fiber optic cable to maintain a suitable bend radius without an external bend relief structure extending rearward on the cable. Moreover, using an end cap as described herein provides a compact and clean-looking connector footprint since no dedicated discrete components such as a boot or overmolded portion are required for cable bend relief.

However, passageway **313** can have any suitable size and/or shape to compliment the cross-section of the cable extending therethrough. For instance, the shape of the passageway may be influenced by the shape of the cable such as round, oval or flat; likewise, the construction/bend radius of the cable can also influence the shape of the passageway. As shown in FIG. **3A**, passageway **313** extending through end cap **217***a* has a funnel-shape for protecting the fiber optic cable **203** during side-bending. As used herein, "funnel-shape" means that the passageway provides a shape that generally transitions from a smaller opening near the front end of the end cap toward a progressively larger opening near the rear end of the end cap so the optical fiber cable can maintain a proper bend radius during aggressive bending as it exits the connector. In other embodiments, the passageway **313** can be tailored for a non-round cable cross-section such as flat or oval which may have different curvatures, tapers and/or radii between the rear opening and the front opening. For example, FIG. **3B** shows a passageway **313** with a tighter profile to cable **203** and FIG. **3C** shows passageway **313** with larger radii near the rear opening **219** such as may be used with cables having a generally flat profile with a preferential bend characteristic. FIG. **3D** shows a passageway **313** having a tapered profile that generally has uniformly tapered sides with the edges having a radius portion near the rear opening **219**.

End cap device **217** may be formed as a single piece or multiple pieces as discussed herein. If end cap device **217** if formed from multiple components they can be formed from the same or different materials as desired. In one embodiment, the end cap device **217***a* may be translucent or transparent depending on the material. If the end cap device **217***a* is transparent or translucent, then the carrier **217***b* may be visible through the end cap device **217***a*. For instance, the carrier **217***b* may support an end of the circuit board and be colored so that it (and its color) is visible through the end cap **217***a*.

Returning to FIG. **2**, the fiber optic cable sub-assembly **201** includes a circuit board **205**, such as a printed circuit board (PCB) or other circuit board configuration. In this embodiment, circuit board **205** includes an electro-optical (EO) active component **207** in operable (i.e., optical) communication with the optical fiber **301**, **303**. Example active optical components **207** can comprise RF chips, photodiodes, VCSEL and/or other components at or near the connector for EO conversion of optical signals to electrical signals or vice versa. As further shown, the optical fibers **301**, **303** may be integrated with the circuit board by way of a lead frame **209** although a total internal reflection (TIR) block, ferrule or other structure may be used to integrate the optical fibers with the circuit board. In such examples, the lead frame **209**, TIR block, ferrule or the like receive and are attached to one or more of the optical fibers **301**, **303**. In other words, the optical fibers are attached to a structure that aligns and supports the optical fibers so that the optical signals are directed to/from the active components for transferring the signal.

The circuit board **205** can comprise any support member configured to mechanically support and electrically connect electrical components. For example, a circuit board can comprise electrical connections such as conductive pathways, signal traces, tracks, wires or other configurations provided on a nonconductive substrate **801** (i.e., a dielectric substrate). As shown in FIG. **8**, the nonconductive substrate **801** may comprise plastic material, resin, composite material (e.g., fiberglass) or other structures configured to mechanically support and electrically connect electrical members. In one example, the circuit board can use lithography to define the electrical patterns. In further examples, the circuit board (e.g., printed circuit board) can include printed conductive traces that may be applied by low resolution inkjet although other printing techniques may be used in further examples. In still further examples, a conductive sheet of metal (e.g., copper sheet), or other conductive material may be laminated on a surface of the nonconductive substrate of the circuit board, and an etching technique may be used to remove selected portions of the conductive sheet to leave behind the electrical connections.

As further shown in FIG. **2**, the fiber optic cable sub-assembly **201** includes a strain relief device **211** configured to attach an end portion **213** of the fiber optic cable **203** to the circuit board **205**, wherein the circuit board **205** provides strain relief for the fiber optic cable **203**. As such, forces from the fiber optic cable **203** can be applied directly to the circuit board **205** by way of the strain relief device **211** which in turn transfers the forces to other portions of the connector such as surrounding housing **219** or other components. Forces from the fiber optic cable **203** are therefore isolated from the connections (i.e., attachment) of the optical fibers **301**, **303** to the circuit board **205** and from a nose piece **1101** to the circuit board **205**, for example, when forming an active optical cable assembly. In various examples of the disclosure, the strain relief device can comprise a sleeve clamped to the end portion **213** of the fiber optic cable **203**. In the illustrated example, the sleeve can comprise a single piece sleeve that is clamped to the end portion **213** of the fiber optic cable **203**. For instance, the sleeve may comprise a deformable material such as metal (e.g., brass, etc.) that may be selectively deformed, for example, by a crimping tool to crimp the sleeve to the end portion **213** of the fiber optic cable **203** by a crimping procedure, but other materials are possible for the sleeve such as polymers or the like. As shown in FIG. **5**, the clamped sleeve can comprise a crimped sleeve **501** formed by crimping a sleeve about the end portion **213** of the fiber optic cable **203** using a crimping tool or the like. In other embodiments, the sleeve **315** could be molded onto the jacket or be a separate dielectric sleeve that is mechanically and/or chemically attached to the cable as desired.

In further examples, the sleeve can comprise multiple sleeve portions that are clamped together. For example, the sleeve can comprise a first portion that is screwed, or otherwise fastened to a second portion. The first and second portion can then be adjusted (e.g., by way of the fasteners), to clamp the first and second portion of the sleeve to the end portion **213** of the fiber optic cable **203**. In further examples, the sleeve may include a set screw or other clamping member configured to clamp to the end of the fiber optic cable. In still further examples, the sleeve may be attached by chemical reaction, adhesive, press-fitting, or otherwise attaching the sleeve to the end portion **213** of the fiber optic cable **203**.

The strain relief device **211** may optionally be configured to be attached (i.e., secured) to the cable jacket **309**, for example, by clamping the sleeve to the outer surface of the cable jacket. For example, as shown in FIG. **5**, the sleeve is crimped to an outer surface **503** of the cable jacket **309**, but other variations for securing the sleeve to the cable are possible. By way of example, the strain relief device **211** may also be configured to be attached to strength members of the fiber optic cable. In other words, a strength member such as a metal wire or aramid material such as Kevlar® or strength element associated with the cable jacket **309** may be secured to the sleeve. For example, the strain relief device may include a sleeve crimped to elongated metal strength members and/or Kevlar® material associated with the fiber optic cable, and in some examples, without necessarily engaging the cable jacket. In still further configurations, the strain relief device may include a connection (with or without a crimped sleeve) between the circuit board **205** and an elongated metal strength members, Kevlar® material, cable jacket and/or other elements associated with the fiber optic cable **203**.

As further shown in FIG. **2**, the strain relief device **211** may also optionally include at least one mounting bracket **215***a*, **215***b* attaching the sleeve **501** (e.g., crimped sleeve or other sleeve configuration) to the circuit board **205**. FIG. **2** illustrates two mounting brackets including a first mounting bracket **215***a* and a second mounting bracket **215***b* although a single mounting bracket or more than two mounting brackets may be provided in further examples. FIGS. **6** and **7** illustrate aspects of each mounting bracket **215***a*, **215***b* that are illustrated as identical to one another. While the mounting brackets may have non-identical configurations according to the concepts of the disclosure, providing identical mounting brackets **215***a*, **215***b*, can reduce the number of unique parts necessary to assemble the strain relief device **211** and therefore simplify assembly and stocking requirements for the brackets. FIG. **6** illustrates a top perspective view of the mounting brackets **215***a*, **215***b* while FIG. **7** illustrates a bottom perspective view of the mounting brackets **215***a*, **215***b*. Each mounting bracket **215***a*, **215***b* can include a central retaining structure **601** configured to facilitate capture of the sleeve **501**. For instance, as shown in FIG. **7**, the mounting bracket may include stops **701***a*, **701***b* defining a receiving channel **704** therebetween. As further shown, a pair of wings **703***a*, **703***b* may extend away from the receiving channel **704** and include engagement structures such as the illustrated tabs **705***a*, **705***b*. The wings **703***a*, **703***b* may also include complementary slots **707***a*, **707***b*. The distance “D” of the tabs **705***a*, **705***b* from the respective edges can be substantially identical to the distance “D” of the complementary slots **707***a*, **707***b* from the respective edges. As such, two identical mounting brackets **215***a*, **215***b* may be arranged with respect to one another such that the receiving channels **704** of the mounting brackets face one another with the mounting tabs **705***a*, **705***b* of one mounting bracket **215***a* being respectively received within the complementary slots **707***b*, **707***a* of the second mounting bracket **215***b*. Likewise, the mounting tables **705***a*, **705***b* of the second mounting bracket **215***b* can be respectively received within the complementary slots **707***b*, **707***a* of the first mounting bracket **215***a*. Simply stated, the mounting tabs and slots of the first mounting bracket are positioned so at to complimentarily engage with the mounting tabs and slots of the second mounting bracket and some embodiments use identical mounting brackets to reduce the number of distinct parts required. This allows the two mounting brackets engage each other (respective mounting tabs and slots) and in this embodiment secure by locking together while sandwiching the circuit board between the mounting brackets as discussed below. Other embodiments may use mounting brackets that do not lock but secure mounting brackets and attach the cable to the circuit board.

As shown in FIG. **8**, the circuit board **205** can include a support structure such at the nonconductive substrate **801** that includes a first engagement structure and the mounting bracket includes a second engagement structure mated with or locked with the first engagement structure for attaching the mounting bracket to the circuit board. In one particular example, one of the first and second engagement structure comprises an aperture and the other of the first and second engagement structure comprises a tab at least partially received by the aperture. Illustratively, the first engagement structure of the circuit board **205** can comprise apertures **803***a-d* while the second engagement structure of the mounting bracket **215***a*, **215***b* can comprise the tabs **705***a*, **705***b* at least partially received in a respective one of the apertures **803***a-d*.

Alternatively, in other embodiments the first engagement structure of the circuit board can comprise a tab while the second engagement structure of the mounting bracket can include an aperture configured to at least partially receive the tab. In further examples, the first and second engagement structure can include other tab features configured to cooperate with one another to provide attachment of the bracket to the circuit board. For example, the tabs may comprise truncated triangles configured to be press fit within the apertures to provide a press fit connection that does not necessarily require a crimping procedure (i.e. folding of the tab) to complete the attachment procedure.

In further examples, the first and/or second engagement structure can comprise distinct and separate mechanical structures such as pins, screws, rivets, jumper wires or the like commonly used with the circuit board assemblies instead of tabs that are integrated with the mounting brackets. Such mechanical structures can cooperate with corresponding structures of the mounting bracket to provide a locking connection between the first and second engagement structure. For instance, notches in the mounting bracket can be used if there were pins or jumper wires (e.g., looped pins), standing up on the circuit board to connect with the notches.

In still further examples, the first and/or second engagement structures may comprise locations suitable to receive a fastening element therebetween to lock the first and second engagement structures. For example, the first and second engagement structures may comprise a surface suitable to receive an adhesive to lock the first and second engagement structures together. In still further examples, the first and second engagement structures may comprise a surface suitable to receive solder such that a solder or weld joint attaches the first and second engagement structures together.

The concepts of the disclosure may use a single mounting bracket for securing the sleeve **501** attached to the end of the cable to the circuit board **205** such as depicted in FIG. **8**. For instance, sleeve **501** may be adhesively or mechanically attached to the single mounting bracket as desired. By way of example, a single mounting bracket could be formed to wrap about two surfaces of the circuit board and attached to the sleeve on both sides of the circuit board instead of using two separate mounting brackets if desired. However, more robust sub-assemblies may be constructed by using a first mounting bracket **215***a* attached to a first side of the circuit board **205** and a second mounting bracket **215***b* mounted to a second side of the circuit board **205** to capture the sleeve **501** between the first and second mounting brackets **215***a*, **215***b*. In other words, the circuit board **205** is sandwiched between the first mounting bracket **215***a* and the second mounting bracket **215***b* and the sleeve **501** is captured between the respective mounting brackets **215***a*,**215***b* and disposed in receiving channel **704**.

Further, as shown in FIGS. **8** and **9**, the circuit board **205** may include an optional opening **805** configured to at least partially, or entirely, receive the end portion **213** of the fiber optic cable **203** within the opening **805** of the circuit board **205**. In addition or alternatively, as shown, the optional opening **805** can be configured to at least partially, or entirely, receive the sleeve **501** within the opening **805** of the circuit board **205**. Providing the end portion **213** and/or sleeve **501** at least partially within the opening can minimize the footprint of the circuit board necessary to mount the sleeve **501** and/or can facilitate a coplanar relationship between a symmetrical plane of the sleeve **501** and a plane of the circuit board **205**. As such, the central axis of the end portion **213** of the fiber optic cable **203** can extend along the plane of the circuit board **205** to help prevent bending moments of the cable with respect to the circuit board when the circuit board receives forces (e.g., provides strain relief) from the fiber optic cable **203**. Providing the end portion **213** and/or sleeve **501** at least partially within the opening of the circuit board can also provide a more compact circuit board footprint, reduce the height of the fiber on the circuit board and center the cable at the back of the housing. Stated another way, using an opening can provide a connector with a shorter length and/or a smaller height for the connector package. As shown, in FIG. **5**, the crimped sleeve **501** can include a crimped width W**1** that is substantially equal or less than the width W**2** of the opening **805** as shown in FIG. **8**. As such, the crimped sleeve **501** can be positioned within the opening to allow the sleeve to be attached to the circuit board **205**.

FIGS. **12** and **13** illustrate another example strain relief device according to the concepts disclosed herein. This strain relief device uses a sleeve **1201** without a separate mounting bracket. Providing a sleeve **1201** without a mounting bracket can reduce parts necessary to fabricate the fiber optic cable sub-assembly, thereby simplifying assembly and reducing inventory requirements. As shown, the sleeve **1201** can optionally comprise a single piece sleeve that may be clamped (e.g., crimped) or otherwise attached to the end portion **213** of the fiber optic cable **203** in accordance with the various methods discussed above. The circuit board **205** can include a first engagement structure and the sleeve **1201** can include a second engagement structure mating and/or locking with the first engagement structure for securing/attaching the end portion **213** of the fiber optic cable to the circuit board **205**. As discussed previously, various engagement structures can be used that cooperate with one another to provide attachment of the end portion of the fiber optic cable to the circuit board. For example, one of the first and second engagement structure can comprise an aperture and the other of the first and second engagement structure comprises a tab at least partially received by the aperture. As shown in FIGS. **12** and **13**, for example, the first engagement structure of the sleeve **1201** can comprise at least one tab **1201***a*, **1201***b* and the second engagement structure of the circuit board **205** can comprise at least one aperture such as the illustrated slots **1203***a*, **1203***b* with the tabs **1201***a*, **1201***b* at least partially received by the apertures (e.g., slots **1203***a*, **1203***b*) to attach the end portion of the fiber optic cable to the circuit board. Of course, sleeve **1201** can have other shapes and/or sizes for securing to the cable and the circuit board.

Still other variations of strain relief devices are possible that do not use a separate mounting bracket as a discrete component. By way of example, FIGS. **14** and **15** illustrate still another example strain relief device that only comprises a sleeve **1401** without a separate mounting bracket. As shown, the sleeve **1401** can optionally comprise a single piece sleeve that may be clamped (e.g., crimped) or otherwise attached to the end portion **213** of the fiber optic cable **203** in accordance with the various methods discussed above. The circuit board **205** can include a first engagement structure and the sleeve **1201** can include a second engagement structure mated and/or locked with the first engagement structure to attach the end portion of the fiber optic cable to the circuit board. As discussed previously, various engagement structures can be used that cooperate with one another to provide attachment of the end portion of the fiber optic cable to the circuit board. For example, one of the first and second engagement structure can comprise an aperture and the other of the first and second engagement structure comprises a tab at least partially received by the aperture.

The alternative example embodiment of FIGS. **14** and **15** the engagement structure for securing to the circuit board is integrated into the sleeve. As shown in FIGS. **14** and **15**, for example, the first engagement structure of the sleeve **1401** can comprise at least one tab **1403***a*, **1403***b* integrated with the sleeve **1401**. In one example, the tabs **1403***a*, **1403***b* may be formed in the sleeve before clamping (e.g., crimping). Alternatively, the tabs **1403***a*, **1403***b* may be formed during or after clamping. In one example, the sleeve is clamped (e.g., crimped) while simultaneously forming the tabs **1403***a*, **1403***b*. For example, a stamping procedure may be used to crimp the sleeve while cutting portions of the sleeve to bend away from the base of the sleeve to form the tabs **1403***a*, **1403***b*. In still further examples, the sleeve may be clamped, then portions of the clamped sleeve may be trimmed and bent to form the tabs **1403***a*, **1403***b*.

Moreover, as shown, the tabs **1403***a*, **1403***b* may optionally be provided at the front end of the sleeve **1401** nearest corresponding end of the fiber optic cable **203**. Providing the tabs **1403***a*, **1403***b* near the front end of the sleeve **1401** can help the sleeve further clamp down on the cable jacket since the tabs **1403***a*, **1403***b* can act as levers against the fulcrum point of the sleeve attachment; thereby resulting in pinching of the end of the sleeve when the fiber optic cable **203** is placed under sufficient tension.

As shown, the at least one tab **1403***a*, **1403***b* comprises two tabs although a single table or more than two tabs may be provided in further examples. In one example, while a single pair of tabs **1403***a*, **1403***b* is shown, in further examples two or more pairs of tabs may be provided to simultaneously engage 4, 6, 8 or more of the apertures **1405***a-d*, **1407***a-d*. Engaging four or more apertures simultaneously with a corresponding number of tabs can help arrest pivotal movement of the sleeve **1401** relative to the circuit board **205**.

As further illustrated, the second engagement structure of the circuit board **205** can comprise a plurality of engagement structures to provide a plurality of alternate attachment locations of the strain relief device to the circuit board. For example, as shown, the circuit board **205** can include a plurality of apertures **1405***a-d*, **1407***a-d* configured to provide a plurality of attachment locations of the strain relief device to the circuit board. Indeed, as shown in FIG. **15**, the tabs **1201***a*, **1201***b* can at least partially received by a respective pair of apertures (e.g., the apertures **1405***b*, **1407***b*) to selectively attach the end portion of the fiber optic cable to the circuit board at one of a plurality of alternate locations.

Optionally, any of the embodiments of the present disclosure may selectively attach the end portion **213** of the fiber optic cable **203** to the circuit board **205** such that the optical fibers **301**, **303** extend along respective non-linear paths from the end portion **213** of the fiber optic cable **203**. For example, as shown in FIG. **14**, the at least one optical fiber comprises at least the first optical fiber **301** and the second optical fiber **303**. As shown in FIG. **15**, the fiber optic cable **203** may be twisted relative to the circuit board so the optical fibers can have a curved path along a length between an end **213***a* of the cable jacket **309** and ends **301***a*, **303***a* of the first and second optical fibers **301**, **303**. Twisting or arranging the fiber optic cable may aid with allowing the optical fibers to have a curved pathway for taking up any excess length or pistoning of the optical fiber that may exist. Other embodiments can provide slack loops for the optical fibers if desired.

In accordance with still further examples of the disclosure, fiber optic sub-assemblies may be used to create a wide range of fiber optic cable assemblies. For example, the fiber optic sub-assembly **201** can be incorporated as part of the fiber optic cable assembly **101** illustrated in FIGS. **1** and **2**. In one example, the fiber optic cable assembly includes a fiber optic cable including at least one optical fiber with the first fiber optic sub-assembly **201** forming a connector at a first end of the fiber optic cable **203**. In further examples, a second fiber optic sub-assembly may be provided at a second end of the fiber optic cable **203**. In one example, the first fiber optic sub-assembly can be substantially similar, such as identical, with the second fiber optic sub-assembly. As such, the fiber optic cable assembly may include the fiber optic cable **203** with the at least one optical fiber **301**, **303**. The fiber optic cable assembly **101** can further include a first and second fiber optic sub-assembly that each includes a respective first and second circuit board **205** including the active optical component **207** in operable communication with respective first and second ends of the optical fiber **301**, **303**. The first and second fiber optic sub-assemblies can each further include respective first and second strain relief devices **211**. The first strain relief device attaches a first end portion of the fiber optic cable **203** to the first circuit board, wherein the first circuit board provides strain relief for the fiber optic cable. Likewise, the second strain relief device attaches the second end portion of the fiber optic cable **203** to the second circuit board, wherein the second circuit board provides strain relief for the fiber optic cable. As such, tension within the fiber optic cable can be transferred to respective forces directly applied to the respective first and second circuit boards.

Referring to FIG. **2**, the fiber optic cable assembly **101** can further include an end cap device **217** with the end cap **217***a* and the carrier **217***b* as shown. As further shown in FIG. **3**, the end cap device **217** further includes a carrier structure **311** as a portion of carrier **217***b* configured to support an end of the circuit board **205** within a housing **219** (see FIG. **10**). Although, this embodiment shows end cap device **217** as two pieces, other variations may configure the end cap device as a single piece if desired. The end cap device **217** further includes a passageway **313** configured to receive a portion the fiber optic cable **203**. In other words, an end portion of fiber optic cable **203** is protected during side-bending due to the funnel-shape of the passageway **313**.

The fiber optic cable assembly **101** can also include a first shield **221***a* and a second shield **221***b* configured to be snapped together to house and shield the circuit board **205**. In this specific embodiment, the carrier **217***b* supports the rear end of the circuit board using carrier structure **311** for attaching the circuit board with the carrier structure being secured between shields **221***a*,**221***b* when assembled (FIG. **11**A) and the front end of the circuit board is electrically attached to a connector nose **1101** for allowing electrical connection with a device. In other words, the carrier structure **311** engages portions of shields **221***a*,**221***b* as depicted for securing the components together. Moreover, the first shield **221***a* may be provided with snapping connectors **223** configured to be snappingly received within corresponding interior notches (not shown) of an interior surface of the housing **219**. Other variations of cable assemblies using the concepts of the application could use other connector noses or the like for similar or other protocols as desired to create other types of assemblies. Still other variations may have a housing **219** that is overmolded about a portion of shields **221***a*,**221***b*.

In accordance with the various example configurations, such as but not limited to the configurations discussed above, methods of assembling a fiber optic cable sub-assembly can include the step of operably attaching at least one optical fiber **301**, **303** to the active optical component **207** of the circuit board **205** (i.e., positioning the optical fiber in optical communication so it can transmit or receive optical signals with the active optical component). The method can then include the step of attaching the end portion **213** of the fiber optic cable **203** to the circuit board **205** using the strain relief device. Once attached, the circuit board can provide strain relief for the fiber optic cable. Indeed, a tension in the fiber optic cable **203** can be transferred directly to the circuit board, rather than other housing components of the connector. Thus, the forces are inhibited from degrading the optical communication between the optical fibers and active optical components, thereby preserving alignment and optical performance.

Various strain relief devices can be used to attached the fiber optic cable **203** to the circuit board **205**. In one example, the strain relief device can comprise various connections, joints, adhesive connections, or other strain relief devices configured to directly attach the end portion of the fiber optic cable to the circuit board. In one example, the method can include the step of clamping (e.g., crimping or the like) a sleeve to the fiber optic cable and attaching the clamped sleeve to the circuit board. For example, as shown in FIGS. **3** and **4**, an uncrimped sleeve **315** may be provided and the end portion **213** of the fiber optic cable **203** may be inserted within the interior area of the uncrimped sleeve **315**. Next, the sleeve may be clamped, such as crimped, to the end portion **213** of the fiber optic cable **203** as shown by the crimped sleeve **501** illustrated in FIG. **5**. As used herein, "clamped" means that the sleeve is secured to the end of the cable by any suitable method such as mechanical and/or chemical methods such examples of mechanical methods are crimping (i.e., deforming the sleeve), mechanically attaching such as using an adhesive, press-fitting, wedging, screwing or threading onto, using a set screw, and examples of chemical methods are chemical reactions, melting or molding a polymer sleeve about the polymer cable jacket, chemically reactive adhesives, and/or other suitable securement methods.

The clamped sleeve **501** can then be attached to the circuit board **205**. For example, the method can include the step of attaching one or more mounting brackets to the circuit board for attaching the clamped sleeve to the circuit board. For instance, as shown in FIG. **8**, the first mounting bracket **215***a* can be positioned relative to a first side of the circuit board with the tabs **705***a*, **705***b* being inserted through respective apertures **803***d*, **803***a* of the circuit board **205**. As shown, the clamped sleeve **501** can then be cradled within the channel **704** of the first mounting bracket **215***a* with the stops **701***a*, **701***b* straddling respective opposed end edges **807***a*, **807***b* of the clamped sleeve **501**.

Next, as shown in FIG. **9**, the second mounting bracket **215***b* can be positioned relative to the second side of the circuit board with the tabs **705***a*, **705***b* being inserted through respective apertures **803***b*, **803***c*. As shown, the tabs **705***a*, **705***b* of the first mounting bracket **215***a* also extend through the respective slots **707***b*, **707***a* of the second mounting bracket **215***b*. Similarly, although not shown, the tabs **705***a*, **705***b* of the second mounting bracket **215***b* likewise also extend through the respective slots **707***b*, **707***a* of the first mounting bracket **215***a*. Once positioned, the clamped sleeve **501** is also cradled within the channel **704** of the second mounting bracket **215***b* with the stops **701***a*, **701***b* also straddling respective opposed end edges **807***a*, **807***b* of the clamped sleeve **501**.

The method can also include the step of crimping the mounting bracket to the circuit board to attach the clamped sleeve to the circuit board although other techniques (e.g., soldering, welding, adhesives, etc.) may also be used with or without the step of crimping. As represented by arrows **901**, **903** in FIG. **9**, the tabs **705***a*, **705***b* of the first mounting bracket **215***a* can be bent down to lock the mounting brackets **215***a*, **215***b* together. Likewise, although not shown the tabs **705***a*, **705***b* of the second mounting bracket **215***b* can also be bent down to further lock the mounting brackets **215***a*, **215***b* together. Once the mounting brackets **215***a*, **215***b* are secured such as by locking together, the clamped sleeve **501** is captured within the respective channels **704** by way of the corresponding stops **701***a*, **701***b* of the mounting brackets **215***a*, **215***b*. Indeed, an axial movement of the clamped sleeve **501** will be limited by an engagement of at least one of the end edges **807***a*, **807***b* by the corresponding stops **701***a*, **701***b*.

FIGS. **12** and **13** illustrate another example of attaching the end portion **213** of the fiber optic cable to the circuit board **205**, wherein the circuit board **205** provides strain relief for the fiber optic cable **203**. For instance, the clamped sleeve **501** can be attached directly to the circuit board **205** without the use of a mounting bracket since the engagement structure is integrated into the sleeve. Indeed, as shown, the crimped sleeve **1201** can include tabs **1201***a*, **1201***b* that may be inserted within apertures (e.g., slots **1203***a*, **1203***b*). As shown by arrows **1301***a*, **1301***b* in FIG. **13**, the tabs can then be crimped to the circuit board such clamped sleeve is effectively crimped directly to the circuit board to attach the clamped sleeve **1201** to the circuit board **205**.

FIGS. **14** and **15** illustrate another example of attaching the end portion **213** of the fiber optic cable to the circuit board **205**, wherein the circuit board **205** provides strain relief for the fiber optic cable **203**. For instance, the clamped sleeve **501** can be attached directly to the circuit board **205** without the use of a mounting bracket. Indeed, as shown, the crimped sleeve **1401** can include integrated tabs **1403***a*, **1403***b* that may be inserted within a selected pair of apertures **1405***a-d*, **1407***a-d*. As shown schematically by the interface **1501**, the tabs **1403***a*, **1403***b* can then be soldered, glued or otherwise attached (e.g., crimping) with respect to the circuit board.

In any of the methods of the present invention, the step of attaching the clamped sleeve to the circuit board can optionally position the clamped sleeve at least partially within the opening **805** of the circuit board **205**. In addition or alternatively, any of the methods herein may also include the step of providing a curved path in the optical fibers by arranging such as by twisting the cable relative to the circuit board. In one example, as shown in FIG. **14**, the method can include the step of operably attaching a pair of optical fibers to the active optical component (e.g., by way of the lead frame **209**). The optical fibers **301**, **303** may be attached while the tabs **1403***a*, **1403***b* face upwardly as shown in FIG. **14**. As such, the optical fibers **301**, **303** may extend along paths that do not cross one another and may even extend parallel to one another as shown in FIG. **14**. Next, the crimped sleeve **1401** may be rotated as suitable such as about 180° about arrow **1409** such that the pair of optical fibers **301**, **303** of the fiber optic cable extend along a respective curved path such as the substantially S-shaped path shown in FIG. **15**. The optical fibers are shown to cross over one another wherein a reduced space can be achieved while still allowing each optical fiber **301**, **303** to extend along a curved path. Allowing the fibers to extend along a curved path can provide more axial flexibility than substantially straight fibers. Indeed, an axial force applied to a substantially straight fiber may apply significant rigidity as the optical fiber resists buckling under the force. However, providing the fibers to extend along a curved path by bending allows flexibility with force application when compared to a substantially straight optical fiber.

In any of the examples herein, the methods may further include the step of electrically grounding the strain relief device to a ground track on the circuit board. For instance, as shown in FIG. **12**, the tabs **1201***a*, **1201***b* may interface with a ground track **1205***a*, **1205***b* to electrically ground the strain relief device.

As shown in FIG. **10**, the method of assembling the fiber optic assembly **101** can optionally continue with mounting the fiber optic cable sub-assembly to the end cap device **217**. The end cap device **217** can be moved forward with the forward end edge of the circuit board being supported by the carrier structure **311**. Next, the first shield **221***a* can be mounted to the circuit board **205**. As shown in FIG. **11**, the second shield **221***b* can then be mounted with respect to the first shield **221***a* such that the first and second shields **221***a*, **221***b* cooperate to shield the circuit board **205**. As shown in FIG. **1**, a rear end of the housing **219** can then be inserted over the nose **1101** and slid down such that the nose **1101** protrudes from the front end of the housing **219**. Once the rear end of the housing **219** abuts the end cap device **217**, the snap connectors **223** engage interior connecting structures of the housing **219** to lock the housing **219** in place. FIG. **11**A depicts a schematic cross-sectional view showing the assembled sub-assembly.

FIGS. **16** and **17** respectively depict a perspective and a cross-sectional view of another sub-assembly according to the concepts disclosed herein. Specifically, this embodiment is similar to the other embodiment, but shows end cap device **217** being translucent or transparent with one or more light pipes **218** in optical communication with one or more light emitted devices **206** disposed on circuit board **205**. This embodiment has light pipes **218** integrally formed with end cap **217***a* and in optical communication with the light emitting devices **218**. Specifically, light pipes **218** extend through apertures in carrier **217***b* with the ends of light pipes **218** adjacent to the light emitting devices **218** as best shown in

FIG. **17**. Consequently, the light pipes can communicate signals and/or codes to the user such as data transmission and/or state of the connection as desired. As shown, the carrier structure **311** supports an end of the circuit board like the other embodiments. Moreover, the carrier **217***b* may be colored (i.e., such as blue or other color) so that it is visible through the end cap **217***b*.

Aspects of the disclosure provide small-form factor connectors on cables by having a strain relief integrally formed in the end cap. The end cap can also be a portion of an end cap device that includes a carrier for attaching the circuit board, but other functionality may be performed by the end cap such as integrating the carrier structure or light pipes as desired. Further aspects of the disclosure can allow the circuit board, rather than other components of the connector, to provide direct strain relief for the fiber optic cable. As such, the connector size and complexity can be reduced. Moreover, the strain relief device may be mounted within an opening in the circuit board to reduce or even prevent any increase in the overall footprint of the circuit board. Still further, one or more mounting brackets may be provided to capture a crimped sleeve within the opening. In some examples, the crimped sleeve can be captured within the opening such that the axis of the end portion of the fiber optic cable extends along a plane of the circuit board. As such, the circuit board may provide strain relief without creating a substantial bending moment of the fiber optic cable relative to the circuit board. Moreover, the crimped sleeve, if provided, can be optionally electrically connected to a ground track of the circuit board to allow EMI shielding in some applications.

It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the invention. For instance, the sub-assembly or connector may have finger grip features for allowing the craft to easily grab and connected or disconnect the assembly from a receptacle. The finger grip features may be ridges, protrusion and/or shape formed in the end cap and/or the housing as desired. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A fiber optic cable sub-assembly comprising:

a fiber optic cable including at least one optical fiber;

an end cap, the end cap having a passageway extending from a rear opening at a rear end of the end cap to a front opening at a front end of the end cap that receives a portion of the fiber optic cable, wherein the rear opening is larger than the front opening for cable bend relief;

a circuit board including an active optical component in operable communication with the optical fiber; and

a strain relief device for attaching an end portion of the fiber optic cable to the circuit board, wherein the strain relief device further comprises at least one mounting bracket attaching the sleeve to the circuit board.

2. The fiber optic cable sub-assembly of claim **1**, the passageway of the end cap having a funnel-shape.

3. The fiber optic cable sub-assembly of claim **1**, wherein the strain relief device comprises a sleeve clamped or crimped to the end portion of the fiber optic cable.

4. The fiber optic cable sub-assembly of claim **3**, wherein the circuit board includes a first engagement structure and the sleeve includes a second engagement structure that interacts with the first engagement structure to attach the end portion of the fiber optic cable to the circuit board.

5. The fiber optic cable sub-assembly of claim **4**, wherein one of the first and second engagement structure comprises an aperture and the other of the first and second engagement structure comprises a tab at least partially received by the aperture.

6. The fiber optic cable sub-assembly of claim **3**, wherein the fiber optic cable further includes a cable jacket that houses the optical fiber, and the sleeve is clamped to an outer surface of the cable jacket.

7. The fiber optic cable sub-assembly of claim **3**, wherein at least one of the strain relief device and the circuit board include a plurality of engagement structures to provide a plurality of alternate attachment locations of the strain relief device to the circuit board.

8. The fiber optic cable sub-assembly of claim **3**, wherein the strain relief device is electrically grounded by a ground track of the circuit board.

9. The fiber optic cable sub-assembly of claim **1**, wherein the at least one mounting bracket includes a first mounting bracket attached to a first side of the circuit board and a second mounting bracket attached to a second side of the circuit board to capture the sleeve between the first and second mounting brackets.

10. The fiber optic cable sub-assembly of claim **1**, wherein the circuit board includes a first engagement structure and the mounting bracket includes a second engagement structure locked with the first engagement structure to attach the sleeve to the circuit board.

11. The fiber optic cable sub-assembly of claim **10**, wherein one of the first and second engagement structure comprises an aperture and the other of the first and second engagement structure comprises a tab at least partially received by the aperture.

12. The fiber optic cable sub-assembly of claim **1**, wherein the circuit board includes an opening, and the end portion of the fiber optic cable is at least partially positioned within the opening of the circuit board.

13. The fiber optic cable sub-assembly of claim **1**, further including one or more light emitting devices on the circuit board and the end cap having one or more light pipes integrally formed therein and in optical communication with the one or more light emitting devices.

14. The fiber optic cable sub-assembly of claim **1**, wherein the end cap is translucent or transparent.

15. The fiber optic cable sub-assembly of claim **14**, further comprising a carrier structure supporting an end of the circuit board within a housing, wherein the carrier structure is colored so that it is visible through the end cap.

16. The fiber optic cable sub-assembly of claim **1**, further comprising a carrier structure supporting an end of the circuit board.

17. The fiber optic cable sub-assembly of claim **16**, further including a shield for housing a portion of the circuit board.

18. A fiber optic cable assembly comprising:

a fiber optic cable including at least one optical fiber;

an end cap, the end cap having a passageway extending from a rear opening at a rear end of the end cap to a front opening at a front end of the end cap that receives a portion of the fiber optic cable, wherein the rear opening is larger than the front opening for providing cable bend relief;

a circuit board including an active optical component in operable communication with a first end of the optical fiber;

a strain relief device attaching an end portion of the fiber optic cable to the circuit board, wherein the strain relief device is electrically grounded by a ground track of the circuit board; and a shield for housing a portion of the circuit board and the active optical component.

19. The fiber optic cable assembly of claim **18**, further comprising a carrier structure supporting an end of the circuit board.

20. The fiber optic cable assembly of claim **18**, further including one or more light emitting devices on the circuit board and the end cap having one or more light pipes integrally formed therein and in optical communication with the one or more light emitting devices.

21. The fiber optic cable assembly of claim **18**, wherein the end cap is translucent or transparent.

22. The fiber optic cable assembly of claim **18**, further comprising a carrier structure supporting an end of the circuit board within a housing, wherein the carrier structure is colored so that it is visible through the end cap.

23. A method of assembling a fiber optic cable sub-assembly comprising the steps of:

providing a fiber optic cable including at least one optical fiber;

providing an end cap having a passageway extending from a rear opening to a front opening where the rear opening is larger than the front opening for providing cable bend relief;

threading an end of the fiber optic cable into the rear opening of the passageway;

operably attaching the at least one optical fiber of a fiber optic cable to an active optical component of a circuit board; and

securing the fiber optic cable to the circuit board using a strain relief device by attaching an end portion of the fiber optic cable to the circuit board by clamping the sleeve to the fiber optic cable and attaching the clamped sleeve to the circuit board.

24. The method of claim **23**, further including the step of providing a carrier structure for supporting an end of the circuit board.

25. The method of claim **23**, wherein the strain relief device is electrically grounded by a ground track of the circuit board.

26. The method of claim **23**, further including one or more light emitting devices on the circuit board and the end cap having one or more light pipes integrally formed therein and in optical communication with the one or more light emitting devices.

27. The method of claim **23**, wherein the end cap is translucent or transparent.

28. The method of claim **27**, further including the step of providing a carrier structure supporting an end of the circuit board within a housing, wherein the carrier structure is colored so that it is visible through the end cap.

29. The method of claim **23**, wherein the step of securing the fiber optic cable to the circuit board using a strain relief device further comprises the step of crimping the clamped sleeve.

30. The method of claim **23**, wherein the step of securing the fiber optic cable to the circuit board using a strain relief device further comprises the step of attaching a mounting bracket to the circuit board to attach the clamped sleeve to the circuit board.

31. The method of claim **30**, wherein the step of securing the fiber optic cable to the circuit board using a strain relief device further comprises the step of crimping the mounting bracket to the circuit board to attach the clamped sleeve to the circuit board.

32. The method of claim **23**, wherein step of attaching an end portion of the fiber optic cable to the circuit board at least partially positions the end portion of the fiber optic cable within an opening of the circuit board.

33. A cable sub-assembly comprising:

a cable having a communication element;

an end cap, the end cap having a passageway extending from a rear opening at a rear end of the end cap to a front opening at a front end of the end cap that receives a portion of the cable, wherein the rear opening is larger than the front opening for cable bend relief;

a circuit board in operable communication with the communication element, wherein the circuit board includes a first engagement structure; and

a strain relief device for attaching an end portion of the fiber optic cable to the circuit board, wherein:

the strain relief device comprises a sleeve clamped or crimped to the end portion of the fiber optic cable; and

the sleeve includes a second engagement structure that interacts with the first engagement structure to attach the end portion of the fiber optic cable to the circuit board.

34. A fiber optic cable sub-assembly comprising:

a fiber optic cable including at least one optical fiber;

an end cap, the end cap having a passageway extending from a rear opening at a rear end of the end cap to a front opening at a front end of the end cap that receives a portion of the fiber optic cable, wherein the rear opening is larger than the front opening for cable bend relief;

a circuit board including an active optical component in operable communication with the optical fiber; and

a strain relief device for attaching an end portion of the fiber optic cable to the circuit board, wherein the strain relief device comprises a first mounting bracket attached to a first side of the circuit board and a second mounting bracket attached to a second side of the circuit board to capture the sleeve between the first and second mounting brackets.

35. The fiber optic cable sub-assembly of claim **34**, wherein the strain relief device comprises a sleeve clamped or crimped to the end portion of the fiber optic cable.

36. The fiber optic cable sub-assembly of claim **35**, wherein the fiber optic cable further includes a cable jacket that houses the optical fiber, and the sleeve is clamped to an outer surface of the cable jacket.

37. The fiber optic cable sub-assembly of claim **34**, wherein the circuit board includes an opening, and the end portion of the fiber optic cable is at least partially positioned within the opening of the circuit board.

38. The fiber optic cable sub-assembly of claim **34**, wherein at least one of the strain relief device and the circuit board include a plurality of engagement structures to provide a plurality of alternate attachment locations of the strain relief device to the circuit board.

39. The fiber optic cable sub-assembly of claim **34**, wherein the strain relief device is electrically grounded by a ground track of the circuit board.

40. The fiber optic cable sub-assembly of claim **34**, further comprising a carrier structure supporting an end of the circuit board.

41. The fiber optic cable sub-assembly of claim **40**, further including a shield for housing a portion of the circuit board.

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